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SLASH DISPOSAL IN PONDEROSA PINE FORESTS OF THE SOUTHWEST

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By G. A. Pearson, *director, Southwestern Forest and Range Experiment Station,* and Arthur C. McIntyre, formerly *junior forester, southwestern region, Forest Service*

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INTRODUCTION

Logging operations in the Southwest invariably leave the forest littered with unmerchantable logs, tops, branches, and needles, which collectively are termed "slash."[2] Because of the fire hazard slash represents, efforts to remove it or reduce its quantity were among the first measures introduced in forest management in this region. Piling and burning was the first method tried. This proved expensive and difficult to apply on a large scale in the early days of national-forest administration. Owing to deficiencies in organization and technic, often the piled brush did not burn cleanly, or the fire was too destructive to living trees. Many forest officers believed that the costs were disproportionate to the benefits obtained, and that the damage to living trees resulting from occasional accidental fires on slash-covered areas was no greater than that caused by burning slash in piles. There was a widespread opinion among timbermen, also, based on the observation that seedlings were often more abundant around old windfalls and tops than elsewhere, that slash favored reproduction. Accordingly, several substitute methods were put into practice that left all or the greater part of the slash variously disposed upon the ground.

[1] *Pinus ponderosa.* Until 1931 the official common name of this species was western yellow pine.

[2] The term "slash" usually includes all kinds of logging debris. The smaller material, including twigs, needles, and branches up to about 4 inches in diameter, is commonly called "brush." Slash-disposal operations usually deal only with this smaller material; as a result the term "brush disposal" is used more or less interchangeably with "slash disposal", and the expressions "brush piles" and "brush burning" are commonly used instead of "slash piles" and "slash burning."

Research in slash disposal in the Southwest began as early as 1908. Preliminary conclusions were that a ground cover of branches and needle litter was of value in protecting young pine seedlings against evaporation and frost. The method known as "lopping and scattering" thus received strong impetus as a silvicultural measure, and was extensively practiced on the national forests between 1910 and 1919. The expected results in natural reproduction failed to materialize, however; and in the meantime several large fires occurred, which tended further to lower the prestige of methods that leave large quantities of slash unburned.

In recent years the trend has been away from the idea of applying a single slash-disposal method over an entire cutting area, toward a flexible system in which the method is varied to meet different conditions within each area. Although a uniform system is still employed in some localities, not uncommonly 2 or 3 methods are applied on a single section.

It is for the purpose of assembling information acquired in part by the process of trial and error through years of practice, in part by experimentation and measurement, and in part by analysis of statistics that this circular has been prepared. The major part of the work dealing directly with slash disposal was done by McIntyre during the years 1925–26. These investigations were correlated with similar concurrent investigations in the Northwest, reported in a recent publication by Munger and Westveld (*3*).[3]

PURPOSES OF SLASH DISPOSAL

The primary purpose of slash disposal is to reduce fire danger to such a degree as to make control a practical possibility. In the Southwest this purpose does not necessarily call for the removal of all slash, nor does it imply that the removal of slash eliminates danger of fire. On cut-over pine areas of the Southwest, where all the slash is left an uncontrolled fire usually kills all the young trees; where the brush has been piled and burned, ordinarily a fire kills most of the trees less than 12 inches in breast-height diameter, but few above that size; and partial slash disposal may save the larger of the trees that would otherwise be killed by fire. On such areas no form of slash disposal can be relied on to give complete protection from fire; the essential purpose is attained, however, if the quantity of inflammable material on critical areas or strategic lines of defense is so reduced that a protective organization can stop fires before they reach large proportions. In using fire to reduce the quantity of slash, care must be observed to avoid damaging advance reproduction, seed trees, and soil to such a degree as to defeat the operation's major purpose.

Secondary purposes of slash disposal, each of which is present in the management of some areas and not in that of others, are to encourage reproduction, (occasionally) to thin reproduction, and to conserve soil and water. The first two are attained sometimes by removing the slash, sometimes by leaving it; the last always calls for leaving it. Under certain conditions these purposes sometimes outweigh fire protection and thus assume major importance.

[3] Italic numbers in parentheses refer to Literature Cited, p. 28.

FACTORS TO BE CONSIDERED IN SLASH DISPOSAL

Among the factors to be considered in formulating a slash-disposal program are volume and distribution of slash, degree of fire danger, silvicultural influences, economic aspects of disposal, and aesthetic values involved.

VOLUME AND DISTRIBUTION OF SLASH

The volume of slash is determined primarily by the character of the stand and secondarily by the character of the cutting. Other things being equal, the volume of slash is greater in the heavier stands of timber, although the volume of timber and that of slash are not directly proportional. Table 1 shows that the volume of brush per acre increases with the volume of timber cut, but that the volume of brush per 1,000 board feet cut tends to vary inversely with the volume of the stand. In explanation of the latter relationship it may be said that in stands of large volume the crowns, though longer, are relatively shorter and tend to be narrower than in light and more or less open-grown stands (table 2). Presumably, wherever the height of the trees is low in proportion to the diameter, as in young stands or on poor sites, the volume of brush is high in proportion to the volume of timber. Horse logging tends to create a larger volume of slash than power logging, because in horse logging it is necessary to cut roads and trails through patches of saplings. No direct comparison has been made among different tree species native to the Southwest with respect to volume of slash. Because of the habit of Douglas fir (*Pseudotsuga taxifolia*), white fir (*Abies concolor*), and Engelmann spruce (*Picea engelmannii*) of bearing many fine branches well down on the bole, these species would be expected to yield a larger volume of slash than ponderosa pine. On account of the small diameter of the limbs, also, a larger proportion of the limb wood of these species goes into the slash piles than in the case of ponderosa pine. In reporting on a slash-disposal study in the Northwest, Munger and Westveld state (*3*): "Measurements of Douglas fir slash indicate the volume to be two to three times that of [ponderosa] pine in a similar stand."

TABLE 1.—*Volume of brush in relation to volume of stand and volume of cut on 16 ponderosa pine areas on the Coconino National Forest, Ariz.*

Gross stand per acre	Gross cut per acre	Net cut per acre	Brush per acre	Brush per 1,000 board feet of gross cut	Gross stand per acre	Gross cut per acre	Net cut per acre	Brush per acre	Brush per 1,000 board feet of gross cut
Board feet	*Board feet*	*Board feet*	*Cubic feet*	*Cubic feet*	*Board feet*	*Board feet*	*Board feet*	*Cubic feet*	*Cubic feet*
4,852	3,288	----------	2,535	771	9,500	7,879	6,565	3,761	477
5,168	3,834	----------	2,269	592	10,200	8,461	7,550	3,089	365
5,725	3,835	----------	2,468	644	11,300	9,265	8,500	3,576	386
6,256	4,728	----------	2,232	472	14,165	11,765	9,914	4,792	407
6,905	5,074	----------	2,192	432	14,600	12,848	11,370	3,629	282
7,549	4,900	----------	2,957	603	15,100	13,252	11,833	3,916	296
8,676	7,868	----------	3,096	393	20,000	17,741	13,997	4,802	271
9,565	7,490	6,001	3,282	438	21,900	19,410	16,017	6,157	317

TABLE 2.—*Average crown dimensions of ponderosa pine in relation to volume and density of stand,*[1] *Coconino National Forest, Ariz.*

Volume per acre	Crown length	Crown width	Trees per acre	Volume per acre	Crown length	Crown width	Trees per acre
Board feet	*Feet*	*Feet*	*Number*	*Board feet*	*Feet*	*Feet*	*Number*
468	28.3	28.3	1.5	14,498	41.4	21.3	44.6
584	27.4	26.3	2.7	15,570	50.4	21.8	36.8
1,283	33.8	27.2	5.7	16,357	43.4	21.2	49.5
4,248	35.0	25.0	15.3	18,320	47.3	21.3	48.8
5,500	40.4	26.7	10.0	19,663	55.2	22.1	35.1
7,304	38.5	21.6	22.0	20,262	51.8	21.4	37.4
8,153	41.8	24.5	17.6	21,424	56.3	21.3	31.8
9,615	44.1	23.6	20.2	23,308	55.7	21.3	34.2
10,521	45.1	22.9	25.8	24,264	58.7	21.5	32.2
12,820	46.8	22.8	30.0	26,593	61.9	23.5	32.2
13,382	45.1	22.7	35.2	28,476	61.9	22.5	34.8

[1] Based on data from 51 sample plots.

Distribution of slash is determined largely by the distribution of trees of the mature-age classes which, under forest management, make up the bulk of the cut. If the mature trees are evenly distributed the slash tends to be evenly distributed; if the mature trees occur in groups, an uneven distribution of slash results. Where a space between groups of mature trees is occupied by younger growth, the falling of logging debris into the midst of the young growth complicates the slash-disposal problem.

Munger and Westveld state (*3*) that in the Northwest power logging scatters the slash more than horse logging. Observations in the Southwest point to a similar relation in the case of steam skidders, but not in the case of tractors.

FIRE DANGER

The most important considerations bearing on the choice of degree and method of slash disposal have to do with fire danger, that is, the chance of fires starting, the chance of their getting beyond control, and the damage they would cause. Fire danger on cut-over areas is determined in part by the presence of slash and by the volume and distribution of slash. Fire records in the Southwest are not complete enough to indicate the relative fire-protection value of each method of slash disposal. The experience of fire fighters indicates definitely, however, that piling and burning, or otherwise completely removing slash, is a distinct aid in controlling fires and that less thorough disposal methods are ineffective in this direction unless supplemented by the construction of firebreaks.

Other factors in fire danger are climate, quantity and character of inflammable material other than slash, accessibility, presence of logging operations, recreational use, and proximity of timberlands not protected from fire.

The prevalence of slash fires furnishes the best available measure of the need of complete removal of slash. Table 3 gives a record of slash fires 40 acres or more in extent on the Coconino Forest from 1916 to 1933. The cut-over area on the Coconino totaled about 100,000 acres at the beginning of the record, and by 1933 had increased to 181,000 acres. On less than 10 percent of the 1933 total had the slash been piled and burned elsewhere than on firebreaks. Both number and acreage of fires have decreased since 1924 (except

in 1928), undoubtedly in great measure as a result of advances in protective organization and in transportation and communication facilities. The Tusayan National Forest, adjoining the Coconino on the west and representing similar conditions with respect to climate and slash, for reasons not fully understood has had fewer fires than the Coconino, although it has had some large slash fires. The other national forests in the Southwest present less of a fire problem than the Coconino and the Tusayan.

TABLE 3.—*Slash fires of 40 acres or more on the Coconino National Forest, Ariz., 1916–33*

Year	Fires	Total area covered by fires	Largest area covered by 1 fire	Year	Fires	Total area covered by fires	Largest area covered by 1 fire
	Number	*Acres*	*Acres*		*Number*	*Acres*	*Acres*
1916	1	40	40	1926	0	0	----------
1917	2	105	60	1927	0	0	----------
1918	6	873	410	1928	3	1,454	980
1919	0	0	----------	1929	0	0	----------
1920	6	2,848	1,180	1930	0	0	----------
1921	0	0	----------	1931	0	0	----------
1922	0	0	----------	1932	0	0	----------
1923	3	222	110	1933	0	0	----------
1924	2	455	280				
1925	0	0	----------	Total	23	5,997	----------

The foregoing warrants the conclusion that in the Southwest, under existing protection provisions, fire danger is not so great as to be entitled to absolute dominance in determining the disposition of logging slash. On the other hand, the fact that as recently as 1928 one fire spread over 374 acres and another over 980 acres points to the undesirability of any appreciable relaxation of efforts to reduce the danger of slash fires.

CLIMATE

In planning slash disposal it is necessary to bear in mind the climatic conditions that prevail in different seasons, localities, and forest types. A survey of climatic conditions in the several forest types of the Southwest has been published (*5*).

The climatic feature that dominates the fire situation in the Southwest is the annual occurrence of two dry periods separated by a midsummer period of high rainfall. As is shown in figure 1, the ponderosa pine zone of Arizona and New Mexico has a prolonged period of low rainfall in May and June (this often extends into July) and another in the autumn months, beginning in September. The period of low rainfall in the autumn sometimes lasts longer than that in May and June. The effect of the May-June drought is intensified by high day temperatures, high wind movement, and low humidity. In October and November, lower temperature comes to the rescue. A more or less pronounced fire season occurs in the fall months, but this is much less acute than the May-June fire season. The mean maximum temperature for June is about 15° higher than that for October, and 25° higher than that for November.

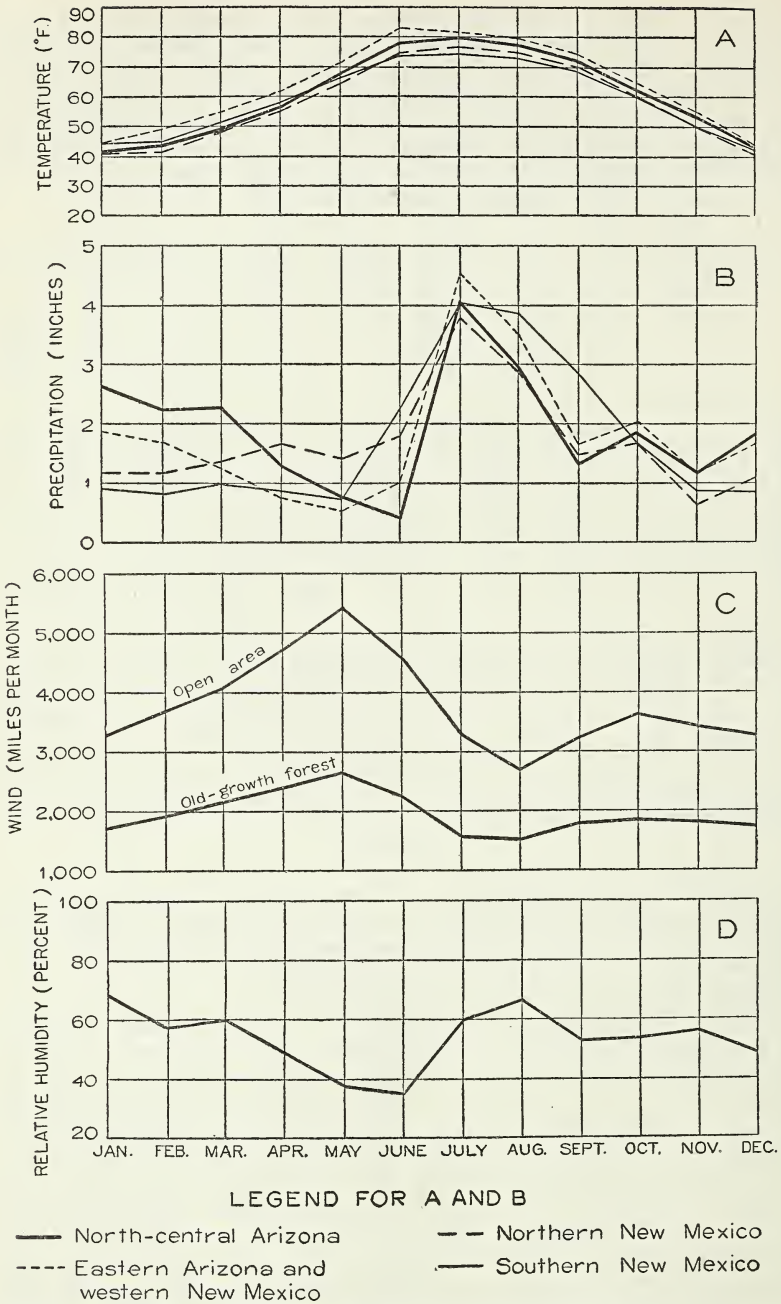

FIGURE 1.—Climatic averages for the ponderosa pine zone of Arizona and New Mexico: *A*, Mean maximum temperature (based on records of several stations covering from 8 to 27 years each); *B*, precipitation (based on records of several stations covering from 6 to 13 years each); *C*, wind (based on records made in Fort Valley, Coconino National Forest, in 1909–12, inclusive); *D*, relative humidity at 8 a. m. (based on Fort Valley records for 1909–12, inclusive).

The May-June fire season is usually more severe in Arizona than in New Mexico. This difference is directly associated with a difference in precipitation. The records presented in figure 1 show distinctly more June precipitation in both northern and southern New Mexico than in Arizona. In northern New Mexico, which includes the Santa Fe and Carson National Forests, precipitation is not deficient in April and May; but in southern New Mexico the entire period from January to June is likely to be comparatively dry. On the Lincoln National Forest, in southern New Mexico, even in the Douglas fir type at high elevations the accumulation of snow is relatively light, and soil moisture is not replenished in the spring by late snow melt such as occurs almost everywhere else in the Douglas fir type. As a result, the spring fire season usually begins earlier on the Lincoln than in northern New Mexico or northern Arizona.

The precipitation graphs for New Mexico suggest that fires might occur there at any time from September on through the winter. Actually, however, very few fires occur after October, because the declining temperatures render even small quantities of precipitation, particularly snow, effective in lowering inflammability.

Bad fires in Arizona and New Mexico are usually the result of a combination of climatic factors. High winds, accompanied by low atmospheric humidity and high temperature, make the most dangerous fire weather. In the absence of high winds slash fires usually can be controlled readily, although in times of low atmospheric humidity and high temperature dangerous conditions sometimes develop through the generation of air currents by a hot fire. The ameliorating influence of decreasing wind, decreasing temperature, and rising humidity is illustrated by the fact that fires are more easily controlled at night. During the early part of the summer rainy season, when lightning starts many fires and the showers are too light to put them out, high humidity and low wind movement are the factors that make it possible to prevent disastrous conflagrations.

FUEL OTHER THAN SLASH

Even if all the slash resulting from a logging operation were removed, usually enough inflammable material would remain on the forest floor to support a destructive fire. Particularly in pine forests, grass is usually abundant enough to enable fires to run between tree groups underneath which leaf litter has accumulated. In well-managed forests, thickets of young trees occupy a considerable portion of the ground area after cutting. Underneath these thickets accumulates a deep layer of needles which, when dry, makes a fire hot enough to ignite the dead branches and finally the crowns. Windfalls, also, form considerable quantities of fuel.

ACCESSIBILITY

The possibility of suppressing fires while they are small is greatly increased by the presence of motor roads. In the pine type of the southwestern region, on all but a few of the cut-over areas any fire can be reached from a ranger station or forest camp within 2 hours of the time it is reported; and since all forest areas are covered by an efficient lookout system and an adequate telephone system, little time is lost in reporting fires. Roads tend to increase the number of

man-caused fires on a given area by making it more accessible to the public; but since about 75 percent of all fires recorded in the region have been caused by lightning, a slight increase in number of man-caused fires does not add materially to the fire problem.

LOGGING

Formerly, fire danger was much greater while logging was in progress than after the operation was completed; in recent years this contrast has largely disappeared on Forest Service lands. This change has been brought about by (1) the substitution of oil or gasoline for other fuels in power equipment; (2) closer supervision in such matters as clearing right-of-ways, regulating smoking, and attacking fires promptly; and (3) the Forest Service policy of holding the operator liable for damage and suppression costs of a fire started by a logging operation on national-forest land. On Forest Service timber-sale areas in the Southwest the fire danger arising from carelessness on the part of woods crews is very slight; that due to carelessness of the general public visiting the camps and driving through cut-over areas is much greater.

RECREATIONAL USE

On forest areas used for recreational purposes, excessive fire danger arises from the use of fire by the public, and potential fire damage may be greater because of the aesthetic values involved. Where recreation predominates over other forest uses, as on strips bordering highways and on public camp grounds, more elaborate treatment of slash may be called for than would be warranted if the primary forest use were commercial production of timber.

PROXIMITY OF UNPROTECTED LAND

Fire risk on national-forest and other protected timberlands may be increased by the proximity of lands that are not adequately protected. Although privately owned timberlands in the Southwest are now for the most part covered by cooperative agreements under which the Forest Service accepts responsibility for fire detection and suppression, because of absence or inadequacy of slash disposal on private lands, there is danger of fires starting on such lands and sweeping onto national-forest lands. Such circumstances call for more complete removal of slash from protected land than might be necessary if all the lands were protected.

SILVICULTURAL INFLUENCES OF SLASH

NATURAL REPRODUCTION

The question is often raised, "Does slash aid or hinder the normal process of natural restocking?" Answers based on experience with a limited variety of conditions have appeared to contradict each other. Although a soil cover of branches and needles usually is not detrimental to natural reproduction and often is beneficial to it, the influence of such a cover varies with the physical condition of the soil and with the character and density of the herbaceous vegetation. The probable silvicultural effect of slash disposal must be considered separately for each area to be logged, on the basis of soil and stand conditions on the area and the known requirements of tree seedlings.

Variations in the influence of slash on reproduction will be illustrated by a brief review of Forest Service experiments and observations having to do with reproduction of ponderosa pine in the Southwest, which are described in greater detail in an earlier publication (*4*).

To obtain information as to whether ponderosa pine seedlings become established better in the shelter of slash than in the open, during the summer of 1908 the slash was lopped and scattered on an area of 126 acres about 8 miles east of Flagstaff, Ariz. The area had been fenced against all livestock. The slash was applied in patches, occupying about half the total surface. During the summer of 1909, germination was good. Counts showed about 12,000 seedlings per acre, both on the slash-strewn areas and on the untreated areas. Examinations through the first fall indicated that brush protected new seedlings against drought and frost. During the next few years, however, practically all the seedlings died, both on the treated plots and on adjoining untreated plots. In 1933 the area was still only partially stocked. No evidence is found that scattering brush has favored the establishment of seedlings on this area.

In 1914 a $\frac{1}{10}$-acre plot in the Fort Valley experimental forest, on the Coconino National Forest, was plowed and heavily seeded with ponderosa pine. Abundant and sustained summer rainfall favored germination. Soon after germination, one of three sample strips extending across the area was lightly covered with scattered brush. Although survival was good over the entire plot, except where damage was caused by white grubs, it was more than twice as good on the brush-scattered strip as on the others. The beneficial effect of brush in this instance, contrasting with the negative effect in the 1908 experiment, is attributed to the fact that herbaceous vegetation was eliminated from the area by plowing before the seed was sown, and to the fact that the brush was applied after instead of before germination. On the area used in the 1908 experiment, bunch grass grew up in the brush and competed with the seedlings; on the 1914 area, no such competition was present and the seedlings received the full benefit of the moisture conserved by the brush.

Unusual opportunities to study the influence of various factors upon germination and survival were provided by the abundant ponderosa pine seedling crop of 1919, which resulted from a heavy seed crop followed by abundant rainfall.

On nearly denuded clayey soils compacted as a result of overgrazing, reproduction was generally poor and most of the seedlings found were grouped in or around scattered clumps of weeds or grass, or in places where the bare soil was covered by litter or logging slash. On sandy or gravelly soils the effect of cover was less evident. On soils rich in organic matter, as in stump patches, where heavy accumulations of litter had rotted down and herbaceous vegetation was closely cropped, seedlings not only became established without cover but grew much more rapidly without cover than where partially shaded or subjected to competition from other vegetation. An explanation of the difference noted is that during germination and early development pine seedlings require a fairly constant supply of moisture in the surface layers of the soil. Heavy, compact soils do not absorb moisture readily, and become very hard when dry. A cover of branches and litter favors absorption of rainfall and retards evaporation. Sandy

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and gravelly soils, and any soils rich in organic matter, absorb moisture readily, and even though exposed to intense evaporation usually contain more available moisture in the root zone of young seedlings than do heavier soils similarly exposed.

On areas well stocked with bunch grass, the survival in 1920 and 1921 of seedlings that germinated in 1919 was generally poorer where slash had been placed than elsewhere except where grazing damage had occurred. In the open spaces grazing held the grasses and other herbaceous plants in check, while on patches where grazing animals were impeded by slash the herbaceous vegetation previously established became very luxuriant. Plate 1, *A*, illustrates this relationship. Numerous counts showed that although germination in 1919 was good in grass, practically all the seedlings died within 1 or 2 years wherever the grass became dense and luxuriant. This observation as to the effect of grass on ponderosa pine seedlings has been corroborated through recent studies (*7*).

Examination in 1919 and 1920 of spots on which brush piles had been burned showed that reproduction varied with soil conditions. On dry, heavy soil, burned spots usually showed poor seedling survival. On less heavy soils they furnished instances of excellent survival and growth. There was evidence that the intensity of the fire might have been a factor in mortality; probably the hottest fires burned the organic matter in the surface soil, as well as removed all the "chunks" which usually remain if the piles are burned when a considerable quantity of snow is on the ground.

Under some conditions, as on clay soils denuded and compacted by years of overgrazing, slash undoubtedly favored pine reproduction of the 1919 crop by conserving moisture. (Prior to 1926 continued overgrazing kept much of the pineland on the Coconino Plateau in the condition just described.) Its greatest effect on reproduction, however, was in preventing livestock from eating the seedlings when they were so small as to be susceptible of complete destruction by grazing. The sites most favorable to reproduction, namely stump patches, logging grades, roads, and in some instances sites on which brush piles had been burned, were subjected to the heaviest grazing, because they bore a relatively succulent type of vegetation or constituted lines of travel for livestock. In 1919 and 1920 the grazing damage to seedlings on such sites, particularly stump patches, commonly amounted to complete extinction, whereas in slash and in bunches of grass and weeds that were not closely grazed a good proportion of the young seedlings usually escaped.

More recent investigations (*6*) have shown that after the second year the mortality of pine seedlings due to browsing falls off sharply.

If slash lies in dense masses it largely prevents seeds from reaching the soil; but seedlings that start in the edges of such masses or in small openings within them make vigorous growth unless other vegetation interferes. When a dense mass of slash breaks down, as it does usually 10 to 15 years or more after logging, it leaves a soil condition favorable to reproduction.

Obviously, slash covers up small seedlings already on the ground when it falls. Its ultimate effect upon seedlings thus covered depends on its density and on the number and size of the seedlings. If the slash is so dense as to cover the seedlings completely, it kills them. If, however, the branches are separated by open spaces and the seed-

ling stand is dense, survival may be adequate. In overdense stands of seedlings, in fact, a desirable thinning can be effected by judicious use of slash.

Because of the many variables involved, it seems futile to attempt to give figures on the proportion of seedlings killed by different methods of slash disposal. For a given set of conditions this proportion can be determined by a few preliminary tests.

CONSERVATION OF SOIL AND WATER

One of the cardinal principles of forest management in the Southwestern region is that on cut-over areas subject to heavy run-off the slash should not be burned but should be disposed in such manner as to promote absorption of water and afford maximum protection to the soil. Accordingly, slash is scattered on sparsely vegetated slopes and concentrated at the heads of gullies and in tractor roads where gullies are likely to form.

Although much can be accomplished by this practice, it should be remembered that the use of brush to lessen run-off and prevent erosion is only a temporary expedient. Brush placed in gullies soon washes out unless run-off is diminished at its source. Brush scattered on slopes cannot be more than partially effective, because the material available usually does not suffice to cover so much as half the land area. Moreover, if overgrazing continues the brush soon breaks down under the effects of trampling, and gullies formed on unprotected spaces cut through the brush-covered ones. The ultimate remedy for excessive run-off and abnormal erosion lies in good silviculture, which includes, together with proper slash disposal, regulation of grazing, fire protection, restriction of cutting, and such other measures as are necessary to establish and maintain a well-stocked and productive forest. If an area is being severely eroded no timber cutting should be permitted until the soil has been stabilized. Regulation of grazing is much more effective in this regard before cutting than after cutting. The leaf litter of standing trees, together with such vegetation as grows in the vicinity of tree groups, makes a more effective soil cover than the somewhat more abundant herbaceous vegetation that may grow up after the timber is removed. Moreover sapling thickets, the undisturbed leaf litter of which creates a soil cover par excellence, become established in the small openings of an uncut stand more readily than in the large openings of a cut-over stand.

TIMBER ROTS [4]

According to Long, the only wood-rotting fungus propagated in ponderosa pine slash that also attacks living trees is the western red rot (*Polyporus ellisianus*). The main characteristics of western red rot were described by Long (*2*) in 1917, before the organism causing it had been positively identified. This fungus, while attacking fallen limbs as well as logs, does not fruit on limbs so small as those commonly handled in any form of slash disposal. Although it has been known to fruit on standing dead trees, in general it fruits only on the under side of logs in contact with the ground. Tops or cull logs that are held off the ground 18 inches or more by projecting branches or

[4] This statement on wood-rotting fungi is derived partly from unpublished material by W. H. Long, forest pathologist, Bureau of Plant Industry. It has been approved by Dr. Long.

otherwise are usually harmless in propagating the western red rot. This fungus usually does not fruit on logs that have been barked or charred, even if these are in contact with the soil.

Trametes pini, which is common in Douglas fir, Engelmann spruce, and corkbark fir (*Abies arizonica*) (and occasionally attacks ponderosa pine), ceases to fruit when the tree is felled. Therefore, slash of these species in mixture with that of ponderosa pine need not be treated to prevent infection of healthy pines with this fungus.

INSECTS [5]

Although various bark beetles of the genera *Dendroctonus* and *Ips* breed in fresh slash, tops, and cull logs of ponderosa pine, it is only under exceptional circumstances that insect conditions necessitate disposal of such material. The more aggressive bark beetles such as *Dendroctonus barberi* and *D. arizonicus* attack felled trees and slash, but usually are not able to increase in such material. If such insects are attracted in large numbers to the fresh slash they may enter and kill nearby standing trees.

Of the genus *Ips* only one species, *I. lecontei*, has proved destructive in the Southwestern region. This species breeds very readily and rapidly in larger cut material and emerges from it in immense numbers. If freshly cut material is lacking, the emerging insects attack and kill nearby trees of sapling or pole size. Such outbreaks usually last no longer than one season; the beetles suffer very heavy mortality in attacking living trees.

In continuous logging operations in the Southwest little or no insect trouble need be anticipated. The more dangerous beetles restrict their activity almost entirely to logs, and their broods are largely destroyed when the logs go through the mill; and although bark beetles breed in tops and large limbs left in the woods, while a logging operation is in progress the emerging broods find plenty of freshly cut material to attack. At the conclusion of the operation, however, the lack of freshly cut material diverts the insects to standing trees. In this situation *Ips lecontei* may prove troublesome for a season. At the conclusion of an operation, therefore, it may be advisable to burn the slash and peel all material more than 4 inches in diameter, before the brood emerges.

ECONOMIC ASPECTS

An important consideration in slash disposal is cost. The more complete forms of slash disposal cost from $3 to $15 per acre. The cost should be weighed against anticipated benefits in the form of decreased fire hazard and improved silvicultural conditions. Another element sometimes contributing to justification of the cost is gain in grazing and recreational values.

The grazing value of cut-over land suffers temporarily if appreciable quantities of slash are left on the ground. This effect decreases with the break-down of slash after about 10 years, but continues in some degree for perhaps 20 years.

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[5] This statement on bark beetles is derived from unpublished reports and correspondence of members of the Bureau of Entomology and Plant Quarantine, and has been approved by F. C. Craighead, chief of the Division of Forest Insects, Bureau of Entomology and Plant Quarantine.

Since removal, by burning or otherwise, is more expensive than other kinds of slash disposal, economy constitutes an incentive for leaving slash on the ground wherever this is consistent with safety and with silvicultural requirements.

AESTHETIC ASPECTS

The appearance of a cut-over forest is enhanced by the burning of slash, or by forms of slash disposal that make the slash less conspicuous and cause it to break down more rapidly. This form of improvement merits consideration especially on areas much frequented by the public. The ugliness of slash, more than anything else, makes even silvicultural cutting repugnant to the average nature lover.

METHODS OF SLASH DISPOSAL

Methods of slash disposal that have been employed or are contemplated in the Southwest include piling and burning, complete or partial; swamper burning; lopping; lopping and scattering; pulling tops; disposal on firebreaks only; and diversified disposal. In piling and burning, the branches are cut into convenient lengths and placed in piles, and these are burned at times when weather conditions make it possible to control the spread of fire. In swamper burning, the green slash is burned as logging progresses by being thrown upon stationary fires. Lopping consists in severing the branches from the bole and, sometimes, cutting them into pieces so that they will lie flat on the ground. In lopping and scattering, after being lopped the branches are dispersed more or less uniformly over the ground. Pulling consists in moving the tops and large branches away from living trees, usually by horse power. Disposal on firebreaks only implies piling and burning on firebreaks, supplemented with intensive fire protection. Diversified disposal is a combination of two or more of the methods just described, varied in accordance with local conditions.

Table 4 gives the acreage on which different methods were practiced on the Coconino Forest in the period 1905–31. The Tusayan Forest record is very similar. On the Sitgreaves Forest, where large cutting operations did not begin until 1920, piling and burning was practiced almost exclusively until 1931, after which diversified disposal including an approximately equal proportion of lopping and scattering was introduced.

In the following pages the various methods will be discussed individually as to technic, efficiency, and costs.

TABLE 4.—*Acreage on which different methods of disposing of ponderosa pine slash were practiced on the Coconino National Forest, Ariz., in 1905–31*

Year	Piling and burning	Piling without burning	Pulling tops	Lopping and scattering	Piling and burning, and lopping and scattering	Pulling and lopping	All methods
	Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
1905			530				530
1906	180		2,980				3,160
1907	480	1,940	2,880				5,300
1908		1,100					1,100
1909		1,440	1,260	240			2,940
1910			820	1,880			2,700
1911			2,200	4,770	160		7,130
1912			960	6,840			7,800
1913		600	2,800	2,580	600	320	6,900
1914		280	5,260	100	320	960	6,920
1915			4,730	100	960		5,790
1916			9,770	200			9,970
1917			10,040	360			10,400
1918			7,210				7,210
1919			9,750				9,750
1920			7,440	250			7,690
1921			5,800				5,800
1922	360		8,480				8,840
1923	1,990	200	4,660				6,850
1924	2,110		2,080	270			4,460
1925	4,070		1,020	30			5,120
1926	760		1,100	1,180	1,480		4,520
1927	720			5,090			5,810
1928	380			3,440			3,820
1929	500			3,610	1,030		5,140
1930	200			1,570			1,770
1931	300			2,300			2,600
Total	12,050	5,560	91,770	34,810	4,550	1,280	150,020
Percent of total acreage	8.0	3.7	61.2	23.2	3.0	0.9	

PILING AND BURNING

PILING

The effectiveness of burning depends in large degree upon the manner of piling. Piling requirements have to do with location, size, and structure of piles.

LOCATION OF PILES

The correct location of a slash pile is determined (1) by the probable damage to tree growth, of whatever age, from the burning of the pile, and (2) by economy of labor in carrying the brush to the pile. As a rule brush piles should not be closer than 20 feet to living trees other than seedlings. (Seedlings at shorter distances generally escape injury because the heat from the burning pile does not pass low enough to strike them.) The proper location of piles is more of a problem where openings in the merchantable stand are occupied by saplings and poles. In such a situation it is sometimes preferable to leave some of the slash unpiled. On areas where fire danger is high it may be justifiable to incur the additional cost of carrying brush out of young stands or of dragging tops out with a team. In dense thickets the burning of a small pile here and there, if properly executed, sometimes results in beneficial thinning. In such cases it is usually advisable to place the piles well within the thicket rather than at the edges, so as to avoid killing thrifty outside members of the group.

Placing brush piles against logs or stumps was formerly considered bad practice, because of the danger from hold-over fires. In order to discourage the propagation of red rot, brush is now, so far as is practical, piled with a view to charring large limbs, logs, and tops left in contact with the ground or in a position to produce fruiting bodies of western red rot. Where such material is supported 18 inches or more above the ground, this precaution is usually unnecessary.

SIZE OF PILES

Large piles are burned more readily than small piles; on the other hand, they generate more heat and consequently must be placed farther away from living trees. For general purposes a pile 7 to 9 feet in diameter at the base and 5 to 6 feet high is most suitable. Where plenty of space is available there is no objection to larger dimensions if these do not involve carrying the brush too far. Where it is necessary to place piles near trees or in groups of saplings a smaller size than that just indicated is preferable, provided this does not result in a spacing so close that the piles may ignite from each other and thus all burn at once. Several small, close-spaced piles burning simultaneously cause more damage than one large pile. Table 5 gives the average dimensions and spacing of piles on a number of areas on the Coconino Forest.

TABLE 5.—*Average dimensions and spacing of slash piles on 15 ponderosa pine areas on the Coconino National Forest, Ariz.*

Gross cut per acre	Height of piles	Width of piles	Piles per acre	Area occupied by piles	Gross cut per acre	Height of piles	Width of piles	Piles per acre	Area occupied by piles
Board feet	*Feet*	*Feet*	*Number*	*Percent*	*Board feet*	*Feet*	*Feet*	*Number*	*Percent*
2,152	4.6	7.8	33.8	3.8	7,490	6.4	11.7	17.5	4.3
3,288	5.4	9.5	13.0	2.1	8,500	5.6	10.9	13.7	2.9
3,834	5.9	10.3	9.2	1.8	11,370	5.5	9.0	20.8	3.0
4,728	5.6	9.7	10.7	1.8	11,765	5.0	9.4	27.6	4.3
4,868	5.5	10.6	12.8	2.5	11,833	5.4	9.4	20.9	3.3
4,900	5.5	10.6	12.7	2.4	17,741	5.2	9.0	35.6	5.1
5,074	5.7	9.8	10.2	1.7	19,410	5.5	10.1	27.9	4.9
6,100	5.0	8.6	13.2	1.8					

TECHNIC

Brush piles should be built according to a definite plan, and not thrown together haphazardly. The primary object should be to obtain a compact mass with a central core of material so readily inflammable that it will ignite even if the outside of the pile is damp from rain or snow. A compact pile sheds water or holds it in the outside layer, whereas a loose pile allows driving rain or snow to penetrate deeply. First, the available small, leafy material is heaped up; the remaining brush is then thrown on, with the convex side up, always in a manner aiming at compactness. Long limbs must be cut down to conform to the dimensions of the pile. The entire mass is bound together by leaning a few heavy limbs against it, preferably with the butt ends inward. It is of utmost importance that the piling be done while the brush is still fresh; later the needles drop off and the branches become stiff, making it difficult to attain the desired compactness.

An undesirable feature common in loosely constructed piles is a flaring base resulting from placing the outside branches in a reclining position instead of standing them on end. The most effective pile is one having a basal diameter but little greater than its height and having almost vertical sides.

Well-constructed piles, both large and small, are shown in plate 2.

A properly constructed pile will burn reasonably clean in snow up to a foot in depth. Loose piles, if burned in snow more than 2 or 3 inches deep, usually leave a ring of unburned material. A small quantity of such material in the form of coarse stubs is not objectionable, except on firebreaks; but the quantity can easily exceed that compatible with effectiveness of disposal in fire control. A burn that succeeded because of the character of the piling, and one that failed because of the character of the piling, are shown in plate 3.

According to present instructions for piling brush in the Southwestern Region, all material more than 4 inches in diameter is left out of the piles. Large branches are cut at a point where their diameter is about 4 inches, the heavier portion being left on the ground or, in the case of tops or cull logs not taken out of the woods, attached to the tree. Limbs thus attached to tops or logs are called "pronghorns." Former instructions prohibited leaving pronghorns, partly for aesthetic reasons and partly because such limbs often hold a log off the ground, thus presumably retarding decay. Not only does the present standard practice of leaving pronghorns result in considerable economy of labor, but there is no evidence of silvicultural disadvantages. As has been pointed out, if logs are held off the ground the fungus *Polyporus ellisianus* usually does not fruit on them. Limb wood more than 4 inches in diameter, whether on the ground or attached to a tree trunk, undoubtedly adds to the intensity of a fire, but does not add appreciably to the danger that fire will get beyond control.

CREW AND EQUIPMENT

The brush crew should be a permanent unit large enough to keep up with the logging operation. Such a crew works more effectively than one varying widely from time to time in size and make-up. The practice of allowing slash disposal to lag and then putting on large numbers of more or less inexperienced men should be discouraged. Good results are obtained by working the men for the most part in pairs, 1 cutting and 1 piling. Ordinarily 2 men can pile the brush from about 10,000 board feet in one 9-hour day. Two pilers to each saw is a good rule. The men should be equipped with double-bitted axes and with a fork for handling fine material. Sometimes it is desirable to use a team for pulling tops out of groups of young trees.

BURNING

The aim in burning slash is to effect fairly complete removal of inflammable material without damaging living trees. If the piling has been properly executed, good results in burning depend primarily on weather conditions at the time of burning. The main factors to be taken into account are moisture and wind.

A, Bunch-grass site on which slash has not been disposed of. The grass has been closely grazed outside the slash, but has grown high within it. On such sites, slash should be piled and burned. *B*, Heavily grazed site on which a few pine seedlings have survived because of protection afforded by logging slash. On such sites lopping and scattering the slash is desirable in order to protect both seedlings and soil.

A, Large slash pile with limb wood on the outside. This type of piling is recommended for areas on which a complete clean-up is desired. *B*, Small slash pile, with coarse limbs left unpiled. The burning of piles such as this, although it does not give a complete clean-up, removes the most inflammable material.

A, Area on which well-constructed slash pile has been burned clean in snow a foot deep. B, Slash pile the burning of which has largely failed because of loose piling.

Slash scattered with convex side up and needle tufts down tends to form a mat that is unfavorable to reproduction but helpful in retarding run-off.

MOISTURE CONDITIONS

The ground and the surrounding litter and grass must be moist enough so that the fire will not run, and it is desirable that this condition continue for several days after the burning is finished, because otherwise fires may start from smoldering embers. The only time when it is really safe to burn brush on a large scale in the Southwest is when the ground is covered with snow and temperatures are such as to permit the snow to remain at least 2 or 3 days. The summer rainy season affords opportunities for burning on small areas that can be watched if the weather turns dry. In most years showers occur almost daily for 2 or 3 weeks at a time in July and August. These rains create conditions favorable for burning, except for the fact that they may cease temporarily at any time and that the relatively high air temperatures and vegetative activity of summer render trees more susceptible to heat than they are in winter.

Usually the cleanest burn is obtainable at the time of the first moderate snows after November 1. Good results can often be obtained after a heavy snow in early winter, by waiting until the snow has melted off the tops of the piles and settled down on the ground to a depth of about 6 inches. Spring is usually less favorable than fall or early winter because brush piles that have lain through the winter are likely to be wet inside. Since a snow blanket is very helpful in protecting small seedlings, where such seedlings are present the greatest depth of snow that permits efficient burning is preferred.

The time during which snow conditions are suitable for brush burning is usually rather limited; but if advantage is taken promptly of favorable conditions as they come, it is usually possible to do all the necessary burning in the course of a winter. Preparedness in having equipment available and in making advance arrangements with the logging foreman for an adequate crew is a large part of the job. Without such preparations several days of good brush-burning weather may be lost in getting slash-disposal operations under way, and by that time conditions may have become unfavorable.

AIR MOVEMENT

High wind is objectionable in its effect on brush burning even when moisture conditions prevent the spread of ground fires, because by carrying heat and flames laterally it endangers leeward trees at what would normally be a safe distance from the pile. When the air is calm the heat rises almost vertically. Simultaneous burning of a group of piles tends to create a strong draft, owing to the inrush of cold air to supplant the rising hot air. On steep slopes a light breeze will carry heat and flames into the crowns of trees on the uphill side of a burning pile. Air currents generated by burning a number of piles at one time are likewise dangerous. Still greater danger lies in the possibility that a fire started at the foot of a slope may ignite the piles higher up, and thus create a general conflagration. For this reason, burning on slopes should proceed not from the base of the slope upward but from the top of the ridge downward.

A great deal can be accomplished toward avoiding damage to living trees by the exercise of judgment in firing individual piles. Sometimes a pile is so situated that even a light breeze from the wrong direction

will result in considerable damage. Such piles might well be left to be burned at another time, or left entirely. This practice may be difficult on large operations where slash from several thousand acres must be burned in a relatively short time. On such operations it is desirable to extend the burning period sufficiently to permit adequate supervision rather than to employ crews so large that they cannot be properly supervised. In large measure, however, need of detailed supervision can be obviated by care in locating piles. If space is not available for placing piles where they can be burned safely, it is better to leave the slash unpiled.

TORCHES

Suitable torches are essential to efficient brush burning. Various simple devices such as pitch sticks or bundles of oil-soaked burlap may be used in emergencies; but on a large job the use of such makeshift equipment increases the cost materially.

The essential features of an effective torch are: (1) A dependable flame of uniform intensity; (2) a form that permits pushing the flame well inside the pile; (3) adequate oil capacity, without too much bulk and weight; (4) simple and economical design; and (5) economical oil consumption.

A torch that meets these requirements and has given satisfactory service in the Southwest is illustrated in figure 2. It is simply a

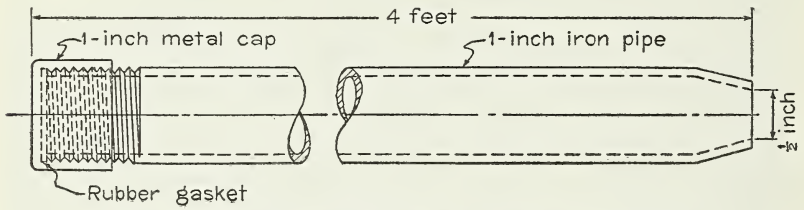

FIGURE 2.—Kerosene torch recommended for burning brush in the Southwest.

1-inch iron pipe 4 feet long threaded and fitted with a cap at one end and drawn out at the other end far enough to be reduced in inside diameter to one-half inch. The inside edges are smoothed so that the wick can be pulled out easily. A round cotton wick is used. The pipe holds enough kerosene to burn 2 or 3 hours, so that it needs replenishment only once during a half day. This torch weighs about 5 pounds.

The Hauck gasoline torch has been used in the Southwest to a limited extent. It has the obvious advantage of supplying intense heat, which facilitates starting fires in damp brush. If brush is too damp to be ignited with a kerosene torch, however, it will not burn well, and much time must be spent rekindling fires and throwing in pieces from the outside of the pile. The Hauck type of torch is heavy to carry and expensive to operate. It can be used advantageously only when brush must be burned under unfavorable conditions and cost is a secondary consideration.

EFFECTIVENESS IN FIRE CONTROL

Piling and burning aims to remove not all ground fuel but merely the most highly inflammable material such as needles and the smaller

branches. After the brush piles have been burned there usually remain enough leaf litter, grass, and limb wood to support a ground fire, but such a fire can be held to a small acreage. The outstanding benefit from brush burning is that any subsequent fires, although they may kill seedlings, saplings, and poles, damage very few seed trees. Perhaps the greatest limitation of piling and burning as a means of fire control is that piled brush resulting from winter logging usually does not become dry enough to burn before spring, and so must lie unburned during the first summer and fall after cutting. Notwithstanding certain shortcomings, piling and burning is more effective in fire control than any other slash-disposal method except possibly "swamper burning", which will be discussed later.

SILVICULTURAL EFFECTS

In effecting a practically complete removal of slash, as has been brought out under the heading Silvicultural Influences of Slash, piling and burning corrects certain silviculturally unfavorable conditions but also destroys certain silvicultural benefits. On good soils occupied by dense grass or deep litter, piling and burning is usually beneficial to reproduction. On poor sites, especially steep slopes, where the soil is highly erodible or tends to become hard and dry, burning aggravates adverse soil conditions and consequently reacts unfavorably upon reproduction. Since the material usually placed in brush piles is too small for the propagation of bark beetles or heart-rot fungi, piling and burning, as generally practiced, has no appreciable effect on these enemies.

COST

The cost of piling and burning varies according to several factors. Brush operations are usually measured in terms of the volume of timber cut. As explained earlier in this circular and demonstrated in table 1, both the volume of brush per acre and the volume of brush per 1,000 board feet of logs vary with the volume and general character of the stand. Other things being equal, the cost of any form of slash disposal per 1,000 feet is least in the heaviest stands of timber. The presence of advance reproduction usually increases the cost, since it adds to the volume of slash (especially in horse logging), increases the carrying distance, and calls for special care in burning. Defect tends to increase costs, because it reduces the scale without reducing the quantity of brush work. Cull logs, which are not limbed by the sawyers and must therefore be limbed by the brush crew, add to the labor without increasing the scale. Limbs from old trees are larger and harder to cut than those from younger trees.

Labor efficiency is, of course, an important item. Indian labor under competent supervision has proved very satisfactory in the Southwest. To contract for labor at a flat rate per pile or per stump is generally more economical than to hire labor at a daily wage. A long walk to and from work, such as is necessitated if the camp is moved before the brush work is finished, increases the cost. Inefficiency of equipment increases the expense of both piling and burning. Piling costs are increased by a snow depth that hampers the movements of the men. Windy weather, deep snow, or improper piling increases burning costs. An item that may increase burning costs very materially is fire patrol, the cost of which is properly chargeable against the operation.

Labor requirements of piling and burning on certain cutting areas on the Coconino, Tusayan, and Sitgreaves National Forests are given in tables 6 and 7. Piling required on an average 2 man-hours per 1,000 feet.

TABLE 6.—*Labor required to pile ponderosa pine brush on 10 areas on the Coconino and Tusayan National Forests, Ariz., in 1923–26*

Gross stand per acre	Gross cut per acre	Volume of brush per acre	Volume of brush per 1,000 board feet cut, gross scale	Labor consumed in piling	
				Per acre	Per 1,000 board feet cut, gross scale
Board feet	*Board feet*	*Cubic feet*	*Cubic feet*	*Man-hours*	*Man-hours*
INDIAN LABOR					
7,549	4,900	2,957	603	10.4	2.11
7,493	4,868	3,096	636	10.1	2.09
11,850	9,550	3,576	374	21.0	1.96
20,586	18,086	6,062	335	23.5	1.30
MEXICAN LABOR					
5,725	3,835	2,468	644	13.0	3.41
9,565	7,490	3,282	438	16.9	2.26
9,500	7,879	3,761	477	14.7	1.91
11,800	9,519	3,972	417	19.0	1.99
12,771	10,271	4,127	402	16.3	1.61
14,165	11,765	4,792	407	17.5	1.48

TABLE 7.—*Labor required to burn brush piles on nine areas on the Coconino and Sitgreaves National Forests, Ariz., in 1923–24*

Area burned	Average cut per acre, gross scale	Labor requirement per 1,000 board feet cut, gross scale	Area burned	Average cut per acre, gross scale	Labor requirement per 1,000 board feet cut, gross scale
Acres	*Board feet*	*Man-hours*	*Acres*	*Board feet*	*Man-hours*
1,800	6,100	0.14	1,100	10,000	0.05
640	6,450	.33	700	10,000	.25
250	6,594	.20	1,280	10,000	.08
215	7,200	.20	640	11,000	.17
160	7,700	.20			

CONDITIONS UNDER WHICH PILING AND BURNING IS APPLICABLE

Piling and burning (or the equivalent "swamper burning", described in the following) is necessary on areas where fire danger is great, especially if high forest values are at stake. Such areas include railroad right of ways, areas bordering on roads and trails, public camp grounds, and recreational areas. The presence of good advance reproduction usually justifies the practice, because young stands are very inflammable and represent high potential forest values. Where the ground is occupied by a heavy growth of grass or by deep litter piling and burning is usually desirable from a silvicultural as well as from a protection point of view, because under these conditions brush retards reproduction and is not needed as a soil cover. Where a good soil cover prevails generally, however, the cover may be deficient in

spots, and for this reason complete piling and burning over large areas is seldom to be recommended.

SWAMPER BURNING

Swamper burning derives its name from the early practice of having the swampers burn the brush in advance of skidding the logs. In the Southwest, wherever this method has been practiced the work has been done by a special brush crew and has not always preceded the skidding. The green branches are thrown on fires located with reference to accessibility to large brush masses and with reference to safety of living trees. If properly executed, swamper burning results in a clean burn and a minimum of damage to reproduction and reserved trees. Because considerable time is required to start the fires, it is economical to burn much larger quantities of slash on one fire than would be placed in one pile in the usual piling and burning. This of course involves carrying slash over longer distances than are usual in piling and burning.

Swamper burning cannot be practiced in dry weather unless unusual precautions are taken to prevent the spread of fire. Ordinarily it is practical only when the ground is covered with snow or wet from recent rains. Swamper burning during the summer rains is subject to the same limitations that govern piling and burning at that season—but in less degree, because the crew can stay in the vicinity of each pile until it is completely burned out. The summer rainy season is quite safe for swamper burning on firebreaks and right of ways, with careful supervision. Obviously, snow affords the greatest safety. Deep snow presents difficulties, however, in that much of the fine material broken from the tree when it crashes becomes buried in the snow and sometimes the snow clings to the branches in such quantities as to interfere with burning. The latter trouble is commonly experienced when slash disposal is a day or more behind the felling, which allows the snow to freeze fast to the needles and twigs. Wind is a less important factor than in burning piled brush, because in swamper burning the fires can usually be so located that the heat is carried away from trees.

For reducing fire danger, swamper burning is the most effective method that has been used. It gives a cleaner burn than can usually be obtained by piling and burning. Another advantage is that it eliminates the usual delay between piling and burning.

Silviculturally swamper burning has the same advantages and disadvantages as piling and burning, with the difference that it causes less damage to reproduction and reserved trees. It is particularly advantageous on areas well stocked with saplings and poles. The burned spots are fewer than in piling and burning. This may be either an advantage or a disadvantage, according to soil and vegetation conditions.

Although swamper burning has not been practiced in the Southwest sufficiently to make reliable cost figures available, the cost is generally conceded to be higher than that of piling and burning. In horse logging, this difference in cost may be offset by a lowering of skidding costs; but horse logging is no longer practiced on large sales in the Southwest. Under present conditions in the Southwest, the method can be used to advantage only in the rare instances in which horse

logging is practiced, or occasionally in clearing firebreaks or right of ways outside the safe burning season.

LOPPING

Lopping, as was previously explained, consists primarily in severing the limbs from the bole, the limbs being allowed to lie as they fall. In more refined practice it includes bringing the larger limbs close to the ground by cutting arched stems and the larger secondary branches. The original purpose of lopping was to place the slash in position to rot rapidly. This end is attained so far as the bole is concerned, but investigations by Long (*1*) have shown that limbs rot more rapidly if left attached to the bole. From the standpoint of fire control and of protecting standing trees from fire damage, lopping accomplishes little or nothing. The method has not been practiced extensively in the Southwest, because in more recent times it has been found to yield very low returns on the expenditure. The labor requirement is about one-half man-hour per 1,000 board feet cut.

LOPPING AND SCATTERING

In lopping and scattering, the brush is placed in openings, wherever possible at least 15 feet away from growing trees above the seedling stage. Large limbs are cut at a point where the diameter tapers to 4 inches, pronghorns being left attached to the bole unless aesthetic considerations call for their removal. The limbs are left in sections as large as can be conveniently handled. They are thrown on the ground usually with the convex side down, because this position results in less matting and thus is more favorable to reproduction. The opposite position, with the convex side up and the needles down, is preferred if the prime object is to retard run-off. This position is illustrated in plate 4. If reproduction is the main object the branches should be dispersed so as to leave open spaces 1 to 2 feet wide and should not be placed on top of each other; the open arrangement admits light needed for seedling development. Each individual area should be studied with a view to holding damage to reproduction to the minimum, unless the seedlings are so dense that a thinning is needed. Immediate results in checking run-off and erosion demand a closer arrangement of the branches; but even where these are the principal consideration the effect on pine reproduction must not be ignored, because ultimately pine thickets make the most effective of all soil covers.

EFFECTIVENESS IN FIRE CONTROL

Lopping and scattering, although it is not recommended where intensive fire protection is necessary, does aid in the control of fires. Scattered brush burns fiercely for a short time, but less sustained concentration of heat results than where brush burns in masses. A fire in scattered brush less than 10 years old does considerable damage, but the damage is less and the fire easier to control than where tops are left intact. In conjunction with lopping and scattering slash, it is necessary to clear firebreaks.

SILVICULTURAL AND OTHER INFLUENCES

The main advantage claimed for lopping and scattering as a slash-disposal method is silvicultural. Creation of a soil cover is the most

immediate effect. This cover delays run-off, thus promoting absorption of water into the soil and retarding erosion, but only on the surface actually covered and during a limited period. It may be expected to favor pine reproduction wherever the ground is comparatively bare, particularly on heavy soils, and to retard it wherever the soil is already deeply covered with litter or occupied by luxuriant herbaceous cover. If the brush is scattered openly enough to permit access by grazing animals, the injurious effects of grass and weed competition are mitigated. On areas subject to overgrazing, scattered brush sufficiently heavy to prevent free access of stock affords partial protection over a limited period (pl. 1, *B*). Control of grazing damage to seedlings, however, like control of soil erosion resulting from grazing, lies in range management rather than in brush disposal.

From an aesthetic point of view, lopping and scattering ranks next to complete removal. Scattered brush breaks down at such a rate that in 5 or 6 years it ceases to be conspicuous. For the best aesthetic effects all pronghorns should be removed and large, crooked branches should be trimmed sufficiently to bring them within about 18 inches of the ground. These measures, however, increase the cost and contribute no silvicultural or protective benefits.

COST

The cost of lopping and scattering is affected by the same factors, in much the same way, as the cost of piling. Under average conditions the labor, which represents practically the entire expense, should not exceed 1 man-hour per 1,000 board feet of timber cut.

FIREBREAKS

On areas where slash has been treated by any method that leaves it unburned, firebreaks are necessary. The cost of firebreaks is properly included in the cost of slash disposal by such a method.

Firebreaks as used in the Southwest are intended not to stop fires automatically but to afford points of vantage from which to combat fires. In this region firebreaks ordinarily bear enough grass and litter so that ground fires will run across them. In a high wind, sparks carry far beyond any firebreak that it is practical to build. The usual method of fire control is backfiring from available firebreaks, roads, etc., and patrolling for spot fires.

The width and frequency of firebreaks needed in the Southwest for effective control varies with the topography and with the volume and character of the slash. Greater width is needed on a slope or in a canyon bottom than on a ridge. Usually firebreaks follow the ridges or broad flats rather than arbitrary courses. They are from 100 to 200 feet wide and are so spaced as to break the area into blocks of about 160 acres each. On areas of exceptional fire danger the units may be smaller, and where the danger is low they may be larger. A large volume of slash per acre calls for wider or more frequent firebreaks.

The clearing of firebreaks involves more work than ordinary piling and burning. All the limbs should be placed in the piles, and it is desirable to remove cull logs and tops. Burning may have to be done under adverse weather conditions, and where the lines run through slash-strewn areas extra precaution must be taken against loss of control.

Table 8 gives a record of the labor requirement of piling and burning slash on firebreaks on several small projects. In these instances the cull logs, tops, and snags were not moved. Unfortunately the cut per acre was not recorded. If the average cut per acre is estimated as 5,000 board feet, the length of firebreak per section as 2½ miles, and the average width as 150 feet, the estimated labor requirement is approximately one-half man-hour per 1,000 feet cut on the entire area. This is the figure generally used in the region. In heavy stands the requirement per mile is higher, but since this is prorated against a correspondingly higher volume of logs the requirement per 1,000 board feet remains about the same or is lower. For wider firebreaks or a more intensive clean-up, a much greater quantity of labor is required.

TABLE 8.—*Labor required to pile and burn slash to form firebreaks on ponderosa pine areas on the Coconino, Tusayan, and Sitgreaves National Forests, Ariz.*

Piling			Burning		
Length	Width	Labor requirement per mile	Length	Width	Labor requirement per mile
Miles	*Feet*	*Man-days*	*Miles*	*Feet*	*Man-days*
1.02	400	176.6	3.50	200	3.43
2.00	400	142.0	.50	100	2.09
3.00	200	58.4	2.50	100	2.90
3.50	200	60.5	1.75	200	4.24
.50	100	59.2	6.25	200	3.99
.50	100	49.5			
1.00	100	41.9			

CONDITIONS UNDER WHICH LOPPING AND SCATTERING IS APPLICABLE

Lopping and scattering is adapted primarily to areas sparsely covered with tree growth, leaf litter, or herbaceous vegetation, particularly on slopes and soil types subject to high run-off. On areas well covered with needle litter or grass, brush adds to the fire danger, is not needed to check run-off, and hinders rather than favors forest reproduction. Even on forest areas having a good cover generally, however, there usually occur spots that are more or less bare; in general, therefore, lopping and scattering has a place on every well-managed forest. It is good practice as an erosion preventive to throw brush in minor gullies and on roads and skidder trails not needed for travel or as firebreaks. It is useless to attempt to dam large gullies in this manner unless the run-off from their drainage areas is controlled.

PULLING TOPS

In the method known as pulling tops, tops and other large masses of brush are pulled bodily away from trees and groups of reproduction in order to decrease the damage in case of fire. The removal distance should be at least 30 feet. Ordinarily a team is used, but in a few instances the work has been done by man power. The practical limitation usually encountered is that adequate open space is not available to remove all the tops to a safe distance. If several tops are placed side by side not more than 30 feet from trees or repro-

duction, fires are likely to cause almost as great damage as if slash disposal had not been attempted.

Only in open stands where very few trees are reserved and where advance reproduction is virtually absent is pulling tops an effective method of fire protection. Silviculturally it has fewer advantages and more disadvantages than lopping and scattering, because the intensity of application is less subject to control. It provides less effective soil cover than lopping and scattering. Its only advantage over lopping and scattering is its lower cost. The labor requirement varies from 0.3 to 0.5 man-team-hours per 1,000 board feet, depending mainly on the density of the residual stand, plus about 0.5 man-hour per 1,000 feet for clearing firebreaks.

This method is applicable to open stands having a small volume of slash and large openings in which tops may be placed without endangering seed trees, poles, and saplings in case of fire.

DIVERSIFIED SLASH DISPOSAL

It has been pointed out that no one method of slash disposal is equally applicable to all the conditions encountered on a cutting area. Although an extensive area may be characterized by certain dominant features such as heavy or light stands, the presence or absence of advance reproduction, conservative grazing or overgrazing, soil and ground cover that are favorable to reproduction or that are unfavorable, careful examination of such an area will usually disclose variations that should be taken into account in disposing of logging slash. Such variations may become still more pronounced after logging. The need for varying the method of slash disposal in accordance with these varying conditions has given rise to the practice of diversified slash disposal, now common on the national forests.

APPLICATION TO A TYPICAL AREA

Diversified slash disposal is illustrated by the proposed treatment of an area typical of a large portion of the uncut pine timber on the Colorado Plateau. Conditions on the area, and the slash-disposal plan, are as follows:

Topography.—Level to rolling, with numerous washes and occasional small canyons.

Stand.—Volume 8,000 to 12,000 feet per acre, about 70 percent mature. Trees mostly in groups. Cutting will leave open spaces 100 to 300 feet in diameter.

Advance reproduction.—Generally good but not complete. Ground beneath and immediately surrounding tree groups usually bare of seedlings, so that when a tree group is cut the spot it occupied will call for restocking. Other unstocked patches will occur. Most of the reproduction is about 45 years old and 3 to 8 inches in breast-height diameter, commonly forming dense thickets. Reproduction of 1914 and 1919 origin is variable, mainly because of past grazing damage. Relatively little browsing is now taking place except on bed grounds, around watering places, and along routes of stock travel.

Soil.—A stony or gravelly clay loam; slopes more or less eroded, but generally favorable to reproduction. Flats usually have a large accumulation of clay, which is productive but is unfavorable to the establishment of seedlings.

Ground cover.—Generally rather sparse on account of past overgrazing. In most places it is of about the right density to promote germination and early establishment of pine seedlings.

Fire danger.—Relatively high because of numerous sapling and pole thickets, which are very inflammable and have a high future forest value. The area is covered by look-outs, and motor roads run within 2 miles of practically all portions of it. Any fire could be reached within a maximum elapsed time of 2

hours by fire fighters in numbers up to 10, and by much larger crews when logging camps are in operation.

Plan of slash disposal.—Although the fire danger is considerable, experience indicates that fires can be controlled without removing all slash. With carefully planned felling, most of the tops will fall in spaces comparatively free of trees above the sapling stage. In the larger openings not well stocked with seedlings the brush will be scattered; where advance reproduction is good the brush will be piled and burned. In openings less than 100 feet in diameter it will usually be necessary to pile and burn part of the brush in order to avoid dense accumulations. On bare-soil areas, except on firebreaks, brush will invariably be scattered to retard run-off or to encourage reproduction. Often the tops from one group of trees will fall in vacant spaces left by the felling of another group. Here the slash should as a rule be piled for burning, regardless of fire-protection needs, because the needle litter already on the ground affords ample soil cover and the addition of brush would retard rather than favor reproduction. Under all circumstances care must be exercised to avoid such concentration of slash in the openings as would cause seed trees at a normally safe distance to be killed in case of fire. Pulling has no place in this type of stand because the tops could not be removed far enough from living trees.

Even with well-directed felling, a considerable number of tops will fall in groups of saplings. These groups are usually so dense that a thinning is desirable, and the breakage caused by a falling tree is really less serious than appearances might suggest. Tops falling into the outer edge of a group can often be dragged out into an opening, or may be piled at a safe distance outside the group. Dragging an unlimbed top through a group of young trees, however, adds to the destruction, and carrying brush out has its cost limitations. In disposing of tops well within groups of saplings, therefore, it will be found most practical to pile what can be burned with reasonable safety and leave the remainder, after lopping the branches that are interfering with young trees. A thorough clean-up involving additional sacrifice of living trees is unjustifiable because the large quantity of leaf litter and dead branches in these thickets, regardless of logging slash, renders them so inflammable that a fire would be sure to destroy them. Sapling and pole thickets are a hazard in themselves, and in case of fire in such stands the object should be to limit the area burned rather than to limit damage within the area covered.

Wheel roads or tractor roads not needed for travel or fire control, steep slopes generally, and incipient gullies should be covered by scattering brush. Well-established gullies require more intensive treatment; as has been explained, when gullies attain large proportions brush dams are ineffective unless attention is given to the drainage area itself.

Firebreaks will be developed almost exclusively from existing logging roads. Tractor roads lend themselves well to this use because of their width and because of the thoroughness with which herbaceous vegetation is eliminated from them. Tractor-logging operations leave a veritable network of roads. Obviously, the roads to be used in the fire-protection scheme should be designated in advance of slash disposal.

COST

The cost of diversified slash disposal varies according to the relative proportion of the total area or volume of slash handled by each of the component methods. Other factors being equal, the cost increases with the proportion of piling and burning, and decreases with the proportion of lopping and scattering or of pulling. As

between individual areas this relation may not hold, because factors other than the method used may be the dominating element in the cost. Table 9 gives the labor requirement, in man-hours, for four small areas. There is reason to believe that in large operations the average would come closer to the lower than to the upper figure. On the other hand, the forest stands now remaining uncut in the Southwest generally have good advance reproduction, which calls for a relatively large quantity of piling and burning.

TABLE 9.—*Labor requirement of diversified slash disposal on four small areas on the Coconino National Forest, Ariz.*

Area cut	Gross scale per acre	Net scale per acre	Brush [1] handled per man-day [2]	Labor requirement		Treatment	
				Per 1,000 board feet net scale	Per acre	Piling	Lopping and scattering
Acres	*Board feet*	*Board feet*	*1,000 board feet*	*Man-hours*	*Man-hours*	*Percent*	*Percent*
580	----------	5,643	6.43	1.40	7.9	[3]	[3]
640	----------	8,890	4.90	1.84	16.4	70	30
640	----------	6,122	4.40	2.05	12.6	80	20
180	7,241	5,809	5.70	1.58	9.2	90	10

[1] In terms of cut, net scale.
[2] 9-hour day.
[3] Figures as to proportion piled and lopped unavailable. 7 miles of firebreak 50 to 75 feet wide constructed along main wheel roads.

DISPOSAL ON FIREBREAKS ONLY

Slash disposal on firebreaks only has not intentionally been practiced on national-forest lands; it has, however, been practiced in effect on national-forest lands acquired after cutting and on privately owned lands within national forests, in the sense that roads and railroad right of ways on such lands constitute firebreaks.

In view of the deficiency of firebreaks on such lands the method cannot be said to have been given a fair trial. Some areas treated in this way have escaped serious fires, but this may be said also of some private lands that have received no protection at all. There is little doubt that with adequate firebreaks and other fire-protection provisions it is possible to control fires on a slash-covered area, although the portion burned and the damage on that portion would be greater than if some form of slash disposal had been practiced. From the standpoint of natural reproduction and soil protection the results would be variable, and in general would be inferior to those obtained where effort is directed toward meeting the peculiar requirements of each condition. Although the method cannot be recommended in intensive forestry, it has merits where forest values and fire danger are low. It may give valuable protection on private land where the owner cannot meet the expense of more effective methods.

Piling and burning on firebreaks only requires from 2 to 3 man-hours of labor for each 1,000 board feet of timber removed from the firebreaks. In addition to the direct cost are the costs of maintaining a protective force greater than is required where all or a large portion of the brush has been removed. Advocates of the method contend that the cost of the additional protective force is less than the saving in cost of slash disposal. The merits of this contention have not been tested in the Southwest.

CONCLUSIONS

Basic principles governing slash disposal on ponderosa pine lands in the Southwest are that removal of slash lessens fire danger, that fire danger is rarely so great as to require complete removal over large areas, that a cover of brush on bare soil promotes absorption of water and lessens erosion, and that a combination of brush with grass or with leaf litter may result in cover too dense for pine reproduction.

Methods of slash disposal in the pine forests of the Southwest should be varied to meet local conditions of fire danger, tree reproduction, soil, and herbaceous vegetation. Since one or more of these factors may change abruptly, it is seldom that any one method can be applied uniformly over a large area. The more nearly the method of slash disposal conforms to conditions on each site or spot within a cutting area the more effective will disposal be.

The methods most applicable are piling and burning (or its equivalent, swamper burning), and lopping and scattering. Occasionally pulling tops or lopping alone is adequate, or disposal is unnecessary, but only on small areas and under special conditions described in this circular. In recent years the most satisfactory results have been obtained through a combination of the first two methods, sometimes with the addition of one of the others. On an area of high fire danger or where forest values are high on account of the presence of good advance reproduction or for other reasons, piling and burning should usually predominate; where fire danger is slight and where the soil needs cover, scattering may be used almost exclusively save for firebreaks; in very open stands lacking reproduction, it is sometimes permissible to employ the less costly method of pulling tops or even to leave the slash as it falls, except on firebreaks.

The actual application of method to site cannot be reduced to specific instructions or rules. If the man in charge of slash disposal understands the basic principles involved he will, with practice, be able to decide at a glance what method should be applied on each site.

Slash disposal ranks in importance with marking and scaling, and it is entitled to an equal share of the supervising forester's attention.

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